Detection of Large Solid Hydrometeors with GPM/DPR

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1. Introduction

A new flag called **FlagHeavyIcePrecip** that signals existence of intense ice or snow precipitation above the -10 degree C height is introduced in Version 5 of the GPM/DPR level 2 products.
The algorithm for it uses only the magnitudes of measured dual-frequency ratio (DFR_m) and radar reflectivity factors together with ancillary temperature data. It is based on the empirical fact that thunderstorms are often associated with strong radar echoes above the height of -10 degrees C. In addition, we use the property that the dual-frequency ratio DFR_m becomes large when precipitation particles are large. Since the ice precipitation particles are generally larger than rain drops, we can expect that DFR_m is larger in ice precipitation regions than in raining regions as long as the attenuation can be ignored. Since spaceborne radar measures precipitation from above the storm, we can generally assume that we can ignore liquid water attenuation above -10 degrees C level.

2. Algorithm

Data: Z_m and DFR_m above the -10 dgrees C isotherm height.

$$\mathrm{DFR_m} = Z_m(\mathrm{Ku}) - Z_m(\mathrm{Ka}) \qquad (Z_m \text{ in dBZ})$$

A. Condition on DFR_m and Z_m at the same range bin

$$x1 = \begin{cases} 10000_b, & \text{if max of } \mathrm{DFR}_m > 7 \text{ dB} \\ & \quad \& \ Z_m(\mathrm{Ku}) > 27 \text{ dBZ}, \\ 00000_b, & \text{otherwise.} \end{cases}$$

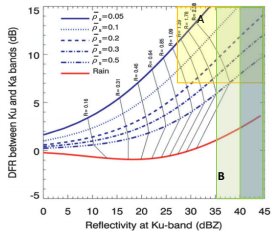
B. Condition on the maximum of KuPR's Z_m

$$x2 = \begin{cases} 00100_b, & \text{if } 35 \text{ dBZ} < \max \text{ of } Z_m(\mathrm{Ku}) \le 40\text{dBZ} \\ 01000_b, & \text{if } 40 \text{ dBZ} < \max \text{ of } Z_m(\mathrm{Ku}) \le 45\text{dBZ} \\ 01100_b, & \text{if } 45 \text{ dBZ} < \max \text{ of } Z_m(\mathrm{Ku}) \\ 00000_b, & \text{otherwise.} \end{cases}$$

C. Condition on the maximum of KaPR's Z_m

$$x3 = \begin{cases} 00001_b, & \text{if } 30 \text{ dBZ} < \max \text{ of } Z_m(\mathrm{Ka}) \le 35\text{dBZ} \\ 00010_b, & \text{if } 35 \text{ dBZ} < \max \text{ of } Z_m(\mathrm{Ka}) \le 40\text{dBZ} \\ 00011_b, & \text{if } 40 \text{ dBZ} < \max \text{ of } Z_m(\mathrm{Ka}) \\ 00000_b, & \text{otherwise.} \end{cases}$$

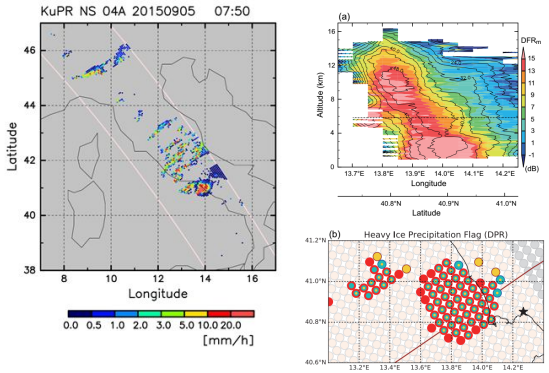
$$\texttt{flagHeavyIcePrecip} = x1 + x2 + x3$$



L. Liao and R. Meneghini, Journal of Applied Meteorology and Climatology, 2011

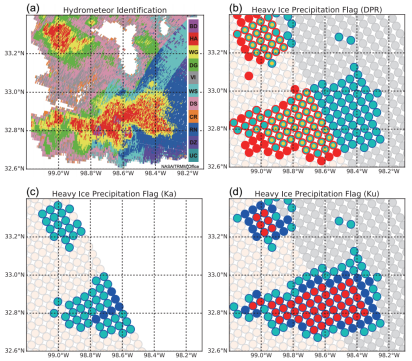
3. Examples

Hail off the coast of Naples, 5 September 2015



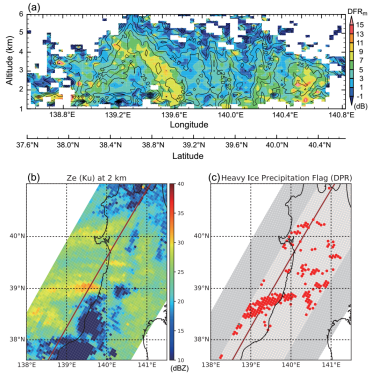
Radar echoes and hail detection off the coast of Naples in Italy on 5 September 2015.
(a) Vertical cross sections of the measured radar reflectivity factor Z_m (contour) with KuPR and DFR_m (color) along the brown line shown in (b). Contour lines are drawn with 4-dB intervals. The broken line at about 6 km indicates the −10°C height.
(b) Heavy ice precipitation flagged by `flagHeavyIcePrecip`. Pixels flagged by conditions A, B and C are indicated by red, cyan and yellow circles. When they overlap, the circles for B and C are reduced to a smaller circle and a dot, respectively. Circles with light grey color indicate outer swath pixels. The location of Naples is shown by a star.

Hail storm near Fort Worth, 26 May 2015



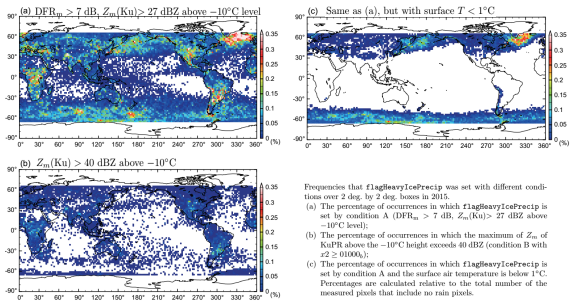
Hail detection in the thunderstorm near Fort Worth on 26 May 2015.
(a) Hydrometeor identification by a ground-based polarimetric radar; BD = big drops /melting hail, HA = hail, WG = high-density graupel, DG = low-density graupel, VI = vertical ice, WS = wet snow, DS = dry snow, CR = ice crystals, RN = rain, DZ = drizzle, UC = unclassified.
(b) `flagHeavyIcePrecip` output from DPR; the pixels are color coded in the same way as in Fig. 1 (b).
(c) `flagHeavyIcePrecip` output from KaPR; cyan: 30dBZ < Z_m < 35 dBZ, dark blue: 35dBZ < Z_m < 40 dBZ.
(d) `flagHeavyIcePrecip` output from KuPR; cyan: 35dBZ < Z_m < 40 dBZ, dark blue: 40dBZ < Z_m < 45 dBZ, red: 45dBZ < Z_m. Circles with light grey color indicate outer swath pixels.

Intense snowfall over NE of Japan, 18 January 2016

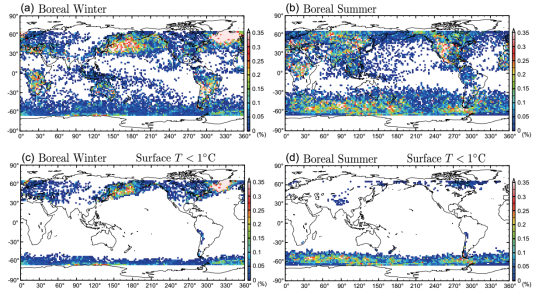


Detection of heavy snow precipitation over northern Japan on 18 January 2016 (local time).
(a) Vertical cross sections of KuPR's Z_m (contour) and DFR_m (color) along the brown line shown in (b) and (c)
(b) Estimated radar reflectivity factor (Z_e) in dB at 2 km
(c) Pixels flagged by `flagHeavyIcePrecip` in DPR product Pixels flagged by conditions A and B are indicated by red and cyan circles. When they overlap, the circles for B are reduced to a smaller circle. Circles with light grey color indicate outer swath pixels

4. Global distributions of flagged pixels



Frequencies that `flagHeavyIcePrecip` was set with different conditions over 2 deg. by 2 deg. boxes in 2015.
(a) The percentage of occurrences in which `flagHeavyIcePrecip` is set by condition A (DFR_m > 7 dB, Z_m(Ku)> 27 dBZ above −10°C level);
(b) The percentage of occurrences in which the maximum of Z_m of KuPR above the −10°C height exceeds 40 dBZ (condition B with $x2 \ge 01000_b$);
(c) The percentage of occurrences in which `flagHeavyIcePrecip` is set by condition A and the surface air temperature is below 1°C. Percentages are calculated relative to the total number of the measured pixels that include no rain pixels.



Frequencies of occurrence of condition A (DFR_m > 7 dB, Z_m(Ku)> 27 dBZ above −10°C level) relative to the total number of measured pixels for
(a) boreal winter (December, January, February) in 2015,
(b) boreal summer (June, July, August) in 2015,
(c) same as (a) but with the surface air temperature less than 1°C,
(d) same as (b) but with the surface air temperature less than 1°C.

5. Summary

1. The new flag, flagHeavyIcePrecip, is set when intense ice or snow precipitation is detected above -10C isotherm.
2. It identifies the intense ice precipitation regions well.
3. The dual-frequency algorithm that utilizes the DFR_m identifies intense snowfall as well.
4. The flagged pixels agree well with the hydrometeor identification by a ground-based polarimetric radar.
5. The DFR_m method is more sensitive to intense ice precipitation than the single frequency method for hail and graupel detection, and it detects intense ice or snow precipitation not only in strong tropical convections, but also in winter storms at high latitudes.